Hybrid PV-T Solar Collector using Amorphous Type of Solar Cells for Solar Dryer

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Abstract—**Solar energy that available in the form of radiation can be directly converted into heat and/or electricity using a solar device collector. Conventional solar thermal collectors generally convert sunlight into heat solely, an the other hand, a photovoltaic (PV) panels usually used solely for generating electricity. In this study, a photovoltaic solar panel is attempted to use both as solar thermal and as electricity generator at the same time so-called hybrid photovoltaic-thermal (PV-T) collector for a solar dryer system. The literature related to hybrid PV-T applications are reviewed, and a small scale solar dryer utilizing amorphous type photovoltaic-thermal (PV-T) as a collector is designed and tested. A 40 Wp amorphous solar panel is used as a solar collector and covered with double glass at the top. The output air temperature of the collector is found to vary from 35 to 50 °C during the day with the global solar irradiation of 300 – 1000 W/m^2. The output of electricity varies 4 – 25 Watt.**

Keywords—solar dryer, PV-T, solar module, solar collector

I. INTRODUCTION

For many kinds of agricultural products, the drying process is an essential process in post-harvest. The productivity and the quality of products are affected by the adequateness of the drying process. In fact, the traditional sun drying to dry agricultural products is still practiced in many places in Indonesia [1]. More appropriate ways need to be attempted to improve the quality of products as well as the hygienists' aspects. At the same time, to improve the productivity and economics of the farmers. The utilization of solar energy using solar dryers is one way for this purpose. Indonesia has advantages for its location around the equator, where solar irradiation is available abundantly throughout the year.

Solar radiation can be directly converted into heat and/or electricity using a solar device collector. Conventional solar thermal collectors generally convert sunlight into heat solely, an the other hand, a photovoltaic (PV) panels usually used solely for generating electricity. In converting solar radiation into electricity, the commercial Solar PV modules give about 17 % [2], [3] of efficiency, which means that it converts the portion of solar energy falling into the modules electricity. The higher remaining energy portion is absorbed by the cells and is converted into heat, which results in a higher temperature of cells. On the other hand, the efficiency of the PV module decreases when the cells temperature and the module increases mean less electricity generated. Higher efficiency can be produced in the form of heat by solar thermal collectors system, and however, in comparison with PV modules (in the similar area of dimension), the solar thermal collectors are commonly more expensive.

One way to increase the amount of harvested energy from solar radiation is by converting it with the combination of thermal or heat and energy electricity generation in one single collector. The system is called Hybrid photovoltaic-thermal (PV-T) collectors. The hybrid PV-T also has the advantage that the PV module gets cooled by the extraction of heat, and therefore it gives higher efficiency. The most important thing that the extracted heat can be used for other heating purposes such as air heating in a solar dryer.

The present studies are to review the development of hybrid PV-T collectors, particularly their use for solar drying. Besides, a small hybrid PV-T solar collector was designed and constructed for a solar dryer. The amorphous PV module type was chosen for it less expensive in comparison to other types of PV cells. A preliminary test was carried out for the dryer, and the results are discussed. The designed dryer in this study is expected to use for drying of herbal material, which is a part of studies in the faculty of pharmacy, University of Surabaya, Indonesia. The hybrid PV-T solar dryer is assumed a good application for such purposes as the heated air could be used directly to dry the products, while and electricity is to supply power to control airflow and temperature in the drying chamber [4].

II. METHODS

The studies in this paper are done both by literature reviews and designing, constructing, and testing a small scale PV-T solar dryer. The literature review is done to review the development of PV-T collectors and its

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application in solar drying. The overall methodology is as shown in the flowchart in Fig.1.

A PV-T solar dryer based was constructed by employing an amorphous type of PV module. The PV modules acted as a solar collector, both thermal and electricity. The module consists of 40 Wp capacity, covered with double glass at the top. To minimize heat loss of the collector, at the bottom and both sides are insulated with rock wool and covered with a zink plate at the outer layer. The specification of the PV module used as a solar collector is presented in Table 1. The drying chamber was constructed separately and connected with the solar collector with a pipe through where heated air flows to the trays in the chamber. The schematic of the dryer is shown in Fig. 2. Preliminary evaluation (with no load), was conducted, and the results are discussed.

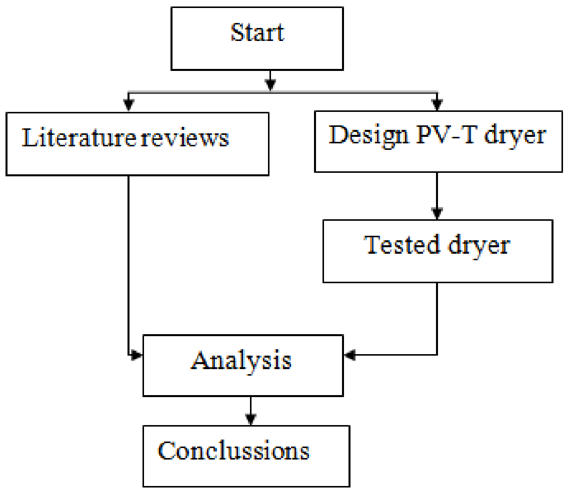

Fig.1. The overall methodology flowchart

TABEL 1. SPECIFICATION OF SOLAR PV MODULE USED

Specifications	Unit/Number/ Type
Solar Panel Type	Amorphous
Dimensions	648x1253x37 (mm)
Maximum Power	40 Watt Peak
Current at max. power	1 A
Voltage at max	46 V
Maximum System Voltage	600 V
Open Circuit Voltage	61 V
Short Circuit Current	1 A

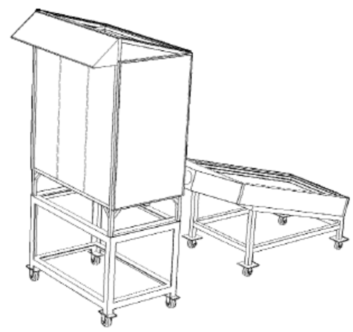

Fig 2. The schematic diagram of the dryer

III. RESULTS AND DISCUSSION

A. *Solar Hybrid PV-T Collectors Review*

A number of researches reported the studies on the topic of solar hybrid PV-T air collectors. The following are the selected publications that were reviewed in this section, and among them are related to the application of solar drying. Sharma et al. [5] and Sebaii & Shalaby [6] reviewed different technologies of the solar dryer. It is reported that very limited studies on the implementation of PV-T technology for solar drying.

Chow [7] and Tyagi et al. [4] reviewed the technologies development of PV-T collectors. They found that the hybrid PV collectors technologies would be a promising type of equipment in the future. Their reviews also show that extensive research on hybrid PV-T system technologies has been carried out during the last 30 years all over the world.

Hegazy [8] investigated the performance of four different models of solar PV-T collectors with a variation of air mass flow and flow ratio. The optimum flow ratio, i.e., channel depth to length, for variable mass flow operation was reported about 2.5 x 10-3. While the optimum air mass flow was found around 0.02 to 0.03 kg/s m². Bambrook et al. [9] reported that additional energy from PV would exceed the power needed by a fan with air flowrate in the range of 0.03 – 0.05 kg/s m². A study on the electrical performance of the mono-crystalline PV module under STC as a result of cooling by forced air ventilation was reported by Kim et al. [10].

Aste et al. [11] studied the performance of a hybrid PV-T collector system was by comparing the results from the real design with the theoretical model. It was found that using double glazing cover on the top of the collector resulted in higher thermal efficiency. This is due to the lower heat losses through the top side. However, due to losses by higher temperature operation, the electrical output decreased by about 16 %[12].

Tripanagnostopoulos [12] reported that the electrical efficiency of the PV module increases by about 1.6% by cooling by using it as an air collector in comparison to the normal operation. It was suggested that the surface of the air channel opposite the PV panel should be made of materials with high emissivity in order to increase the radiation heat transfer. The possibility of increasing the heat transfer into the air was also studied. The air channel was modified to be like small fins on the surface, and placing small tubes and thin metal sheet in the air channel. These modifications resulted in the raising of the opposite air channel wall temperatures.

The air channel depth effects in the solar PV-T collectors were investigated by Farshchimonfared et al. [13] Solar PV-T collectors with different area dimensions were studied. The purposes of the studies were to identify the optimum length/width ratio of the collectors. The size of the total area corresponds to the optimum air channel was investigated. The results showed that the collector width is proportional to the air mass flow rate per unit collector area.

The effect of the airflow and heat transfer in the air gap behind PV cells was studied and reported by Persson [14]. It was reported that only a small portion of heat would be transferred from the PV modules to the air. It is estimated that the transferred heat varies from 7 - 26 %, and it depends on the air velocity. Tiwari et al. [15] investigated the performance under the no-load condition of a mixed-mode PV-T solar dryer. The generated electricity by the PV module was used to supply power for a fan in the drying system for air circulation.

B. Desain of a Small Scale PV-T Solar Dryer

A small scale solar dryer that using a hybrid PV-T solar collector was designed, constructed, and preliminarily tested. As earlier mentioned, the solar PV-T collector consists of 40 Wp amorphous type PV panels with specifications, as shown in Table 1. The diagram and component of the solar collector are shown in Fig. 3. The amorphous type of PV was chosen for its cheaper in price (even though lower efficiency). The lower efficiency PV panel would be a wider dimension than then the other types with higher efficiency for the same power capacity. On the other hand, the wider area would be an advantage for its function as a solar thermal collector.

The built solar collector is connected with a drying chamber contains drying trays. The photograph of the solar dryer is shown in Fig. 4. The connection is through the outlet air of the solar collector by using a PVC duct pipe. The drying chamber is equipped with four small DC fan installed on the top. The purpose of the fan is for air circulation. In operation, fresh air flows through the air inlet channel and gets heated in the solar collector by solar radiation. The heated air is used directly as a drying medium in the drying chamber.

The electricity generated by the PV panels is directly used to supply power for the fan. The electricity system has no battery storage. The DC fans operating speed may change over time according to the power from the PV panels. During higher solar radiation, the heat is collected would be higher as well, which means that the air temperature is also higher. At this moment, a higher speed of fans is needed, which possible by a higher electricity power from the PV. The solar panel was tested with the fixed position, i.e., solar collector facing north, following the optimum position according to the site astronomical position of Surabaya.

From the preliminary test of the solar dryer with no load, it is found that the temperature of the outlet air from the PV-T solar collector varies 35 – 50 ^{o}C corresponds to solar irradiation of varies 300 – 1000 W/m2. In parallel time, the electricity generated by the PV panel varies 4 – 25 Watt. With this output power variation, it was affecting the speed of the circulating fan. During operation, the average air temperature in the drying chamber (obtained from the solar collector), in comparison to the ambient, is shown in Fig. 5. It can be concluded that the PV-T solar collector, using an amorphous type of PV cells, works well as a solar thermal and electricity collector for the dryer.

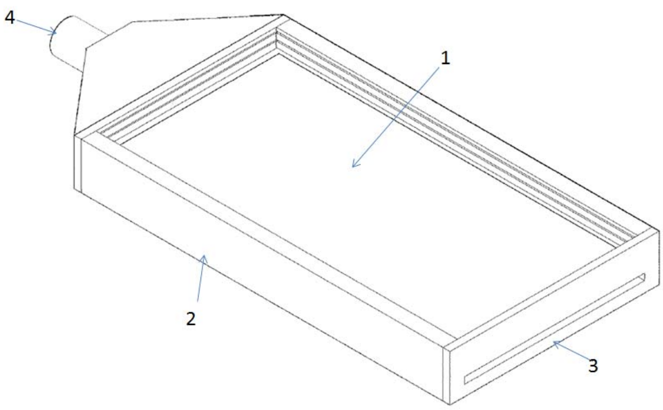

Fig. 3. Diagram of hybrid PV-T solar air collector: 1=Amorphous type of PV panels with double glass covered; 2= insulation at the left, bottom and right sides; 3 = air inlet; 4 air outlet

Fig. 4. Photograph of a small scale PV-T solar dryer

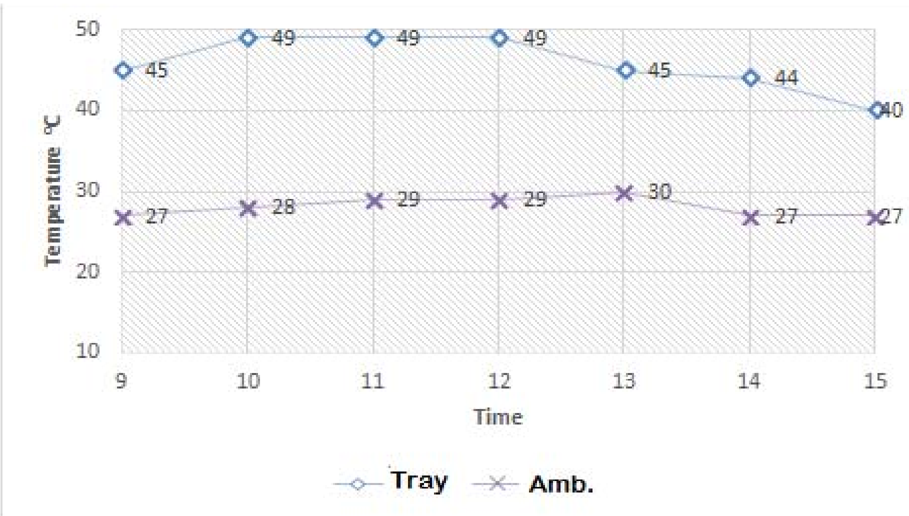

Fig. 5. Temperature in the drying chamber in comparison with ambien

IV. CONCLUSIONS

Hybrid photovoltaic-thermal (PV-T) collectors system generates heat and electricity in one single collector. This way would increase the amount of harvested energy from solar radiation. In this study, a solar dryer that using hybrid PV-T has been preliminarily tested with no load. The results show that the amorphous type of photovoltaic-thermal works well as a solar collector for a solar dryer with drying temperature around 50°C The average electricity power generated from 40 Wp double glazed the amorphous solar panel was about 15 Watt which appropriates to supply a circulated fan for the dryer.

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